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The effect of endodontic solutions on resorcinol-formalin paste

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

by

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Abstract

THE EFFECT OF ENDODONTIC SOLUTIONS ON RESORCINOL-FORMALIN PASTE

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

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This study determined if any of four endodontic solutions would have a softening effect on resorcinol-formalin paste and if there were any differences in the solvent action between these solutions. Resorcinol, formalin and zinc oxide were mixed and allowed to set for 30 days. The solutions tested were 0.9% sodium chloride, 5.25% NaOCl, chloroform and Endosolv R. Seven samples per solution were tested and an additional seven samples served as controls.

Each sample was saturated with one of the solutions and the depth of penetration was tested at 1 min, 2 min, 5 min, 10 min and 20 min using a dial strain gauge. At 2 minutes, NaOCl and sodium chloride had significantly greater penetration than the other groups (p-values < 0.0010). Sodium hypochlorite was superior to all other groups after 5 minutes. This study showed that both sodium chloride and NaOCl exhibited a significant softening effect within two minutes.

Introduction

The overall goal of root canal obturation is a three-dimensional fill of the root canal system. Grossman (1) stated that the ideal root canal filling should be easily introduced into the canal, seal the canal laterally and apically, not shrink, be impervious to moisture, bacteriostatic, radiopaque, not stain tooth structure, not be irritating to the periapical tissues, be sterile before insertion and should be able to be removed easily from the root canal if necessary. Although it doesn't fulfill all of the above requirements, gutta-percha, in one of its many forms, is currently considered to be the best root canal obturating material.

Pastes have been used to obturate root canals and are classified as either zinc oxide-eugenol (ZOE) or resin (non-ZOE) pastes. Due to a lack of apical control and subsequent toxicity of the paste materials that have been overextended into the periapical tissues, they have not been highly regarded as appropriate root canal filling materials.

Some Eastern bloc countries, most notably Russia, still use resin pastes for the treatment of pulpitis (2). Although there are many variations of the resin pastes that are used, the main ingredient is resorcinol. This material is a white crystalline powder that turns pink when it comes into contact with air and light, or with iron. A common mixture used for root canal obturation is made up of resorcinol, zinc oxide and formalin. These three agents are mixed together to form a paste which is then placed into the root canal. When set, this material creates an almost impenetrable barrier and changes the color of the tooth structure to a shade of red or pink. Frequently this resin paste is placed without adequate debridement of the root canals and this may eventually result in a situation whereby many of the teeth demonstrate persistent or recurrent periapical pathology. If these teeth are to be retained, they will either require retreatment or periradicular surgery. As the immigrant population who has received this type of endodontic treatment increases in the United States, dentists are faced with the problem of how to retreat these cases.

The most popular retreatment method presently being used to remove hard resin pastes from obturated canals is by mechanical means that employ burs, files and/or ultrasonic devices. These mechanical methods have the disadvantages of possibly resulting in root perforations, canal straightening and/or alterations of the original canal shape (3). If an adequate solvent was available that would soften the resin, it would help to overcome many of the potential problems inherent in these mechanical methods. Resorcinol alone is known to be freely soluble in certain volatile chemicals such as ether and glycerol (4). Unfortunately, these materials are toxic to vital tissues and root canal retreatment using these chemicals is unwarranted and dangerous. Cohen (5) found that the most effective solvents for softening formaldehyde resin pastes were those that had potentially harmful effects. Some of the effects included irritation to the exposed vital tissues and an environmental risk for both the dentist and patient due to exposure to the solvent vapors. It is unrealistic to expect dentists to employ these potentially harmful solvents when retreating resin-filled canals. The question then becomes: are there any of the commonly used endodontic solutions that can be used to soften this material?

This study was designed to determine if any of four common endodontic solutions would have any significant softening effect on the set resorcinol material and if there were any differences in the solvent action between these four solutions.

Materials and Methods

The resorcinol materials with specific instructions for use were obtained from a Russian dentist. The instructions were translated into English and called for formalin to be added to the resorcinol crystals until the saturation point was just exceeded. Zinc oxide powder was then added to this mixture until a paste-like consistency was attained. A pilot study was undertaken to quantify the amounts of each agent needed to have a mixture that would set and would be reproducible. The pilot study resulted in a resorcinol-formalin mixture that was made by mixing 0.10 ml formalin with 0.40 gm resorcinol to obtain a mix that was just beyond the saturation point of the resorcinol crystals. Zinc oxide in the amount of 0.20 gm was then added to obtain the paste-like mixture. The resulting mixture was then placed into a dappen dish and lightly condensed with a 4-mm diameter single-ended condenser to create a flat surface. The samples were allowed to set in air for one month. The four endodontic solutions tested were 0.9% sodium chloride (Baxter, Deerfield, IL), 5.25%

sodium hypochlorite (Jones Austin Co., Mars, PA), chloroform (Endoco, Memphis, TN) and Endosolv R® (Septodont, Saint-Maur, France). The latter is marketed as a material that will specifically soften phenolic-based resin materials. A resorcinol sample, not treated with any of the solutions, served as the control. Seven resorcinol samples per solution constituted the four test groups and an additional seven samples served as controls for a total of 35 samples tested.

Each dappen dish containing the set resorcinol material was secured to a dial gauge stand (Mitutoyo, Japan). This was accomplished by stretching two elastics across the dappen dish and securing them on the opposite side of their origin. This pressed the dappen dish against the solid back plate of the dial gauge stand so that no movement would occur during the course of the experiment. To assess if the surface of the test material was softened, the dial gauge stand was equipped with a 0.06-inch diameter carbide needle loaded with a 12 g weight. A separate pilot study determined that 12 gm was the proper weight needed to exert the force necessary to test the set material without penetrating the surface of the set mixture. The needle was lowered onto the resorcinol mixture and a baseline reading was taken from the dial gauge. The needle was then raised and the surface of the set resorcinol was covered with 0.05 mg (approximately 5 drops) of one of the test solutions. The needle was then again lowered into the resorcinol. After 1 minute a test reading was taken and the needle was raised. Another drop of test solution was placed on the resorcinol and the needle was again placed in the same position. The process of raising the needle, administering the test solution and lowering the needle back into the solution took approximately 10 seconds. This procedure was repeated at time intervals of 1, 2, 5, 10, and 20 minutes for each sample and test solution. Timing was continued to the 20 minute end point whether or not complete softening was achieved.

The total depth of penetration of each solution was determined by subtracting the 20-minute depth measurement from the baseline measurement. The depth of softening of a sample at an individual time point was determined by subtracting each time period measurement from the previous time period measurement (ie—the 1-minute time point measurement was determined by subtracting the 1-minute depth measurement from the baseline measurement, the 2-minute depth measurement was determined by subtracting the

2-minute depth measurement from the 1-minute depth measurement, etc.). A repeated-measures ANOVA was used to test whether there was a non-zero penetration at each time interval and to test whether there was a significant difference between the four solutions. A comparison of the solutions at each individual time point was assessed by Tukey's Honestly Significant Difference (HSD).

Prior to the initiation of the experiment a power analysis was performed based on comparable information in the Wennberg study (6) to indicate that with a sample size of four, this study would have over 99% power to detect differences in penetrations of 0.075 mm or greater. This study was undertaken with a sample size of seven per solution.

Results

In order to assess the change in penetration across time, a repeated-measures ANOVA was used. The dependent variable was the change in penetration as compared to the baseline. These average differences are shown in Table 1. There was a significantly different trend across time for each softening agent. The different trends are shown in Figure 1.

Within the control group and the chloroform groups, there was no significant difference across the 5 time points (p-values = 0.9979 and 0.0834, respectively). Within the Endosolv R, NaOCl, and Saline groups there was a significant increase across time (p-values < .0001). As can be seen by the confidence intervals in Table 1, within the Endosolv R group, penetration was significant at 2 minutes and all remaining time points. Within the NaOCl and saline groups, penetration was significant at all time points after the baseline values.

At one minute, the five groups were not significantly different (p-value = .3071) but there was a significant difference seen at two minutes and each time period thereafter. At two minutes (p-values < 0.0010), the control group had a significantly lower value than the NaOCl and saline groups. The value for the chloroform group was significantly lower than that for the NaOCl, saline and Endosolv R groups. Endosolv R group values were significantly lower than those for the NaOCl group, but were significantly greater than those for the chloroform group. There were no significant differences seen between the Endosolv R, the saline or the control groups at this time period. The saline group values were significantly higher than the values for control and chloroform groups but were not significantly different from those for the NaOCl or Endosolv R groups. Values for the NaOCl group were significantly higher than those for the Endosolv R, control and chloroform groups but were not significantly different from the saline group.

At five minutes, 10 minutes and 20 minutes the NaOCl group was superior to all the other groups in softening the resorcinol material. At these same times, the saline group was superior to the chloroform and control groups but was not different from the Endosolv R group. The Endosolv R, chloroform and control groups were not significantly different from one another at any of these three time periods.

TABLE 1 Mean Change In Penetration Across Time (95% Confidence)

Softener	p	Minutes	Mean Difference	95% Confidence Interval
Control	0.9974	1	0.033	(0, 0.119)
		2	0.041	(0, 0.127)
		5	0.043	(0, 0.129)
		10	0.043	(0, 0.129)
		20	0.043	(0, 0.129)
Chloroform	0.0834	1	0.022	(0, 0.108)
		2	0.036	(0, 0.122)
		5	0.054	(0, 0.140)
		10	0.075	(0, 0.161)
		20	0.117	(0.031, 0.203)
Endosolv R	<0.0001	1	0.080	(0, 0.165)
		2	0.127*	(0.041, 0.213)
		5	0.166*	(0.080, 0.252)
		10	0.210*	(0.124, 0.296)
		20	0.276*	(0.190, 0.362)
NaOCl	<0.0001	1	0.111*	(0.025, 0.197)
		2	0.248*	(0.162, 0.333)
		5	0.460*	(0.374, 0.545)
		10	0.608*	(0.522, 0.694)
		20	0.741*	(0.655, 0.826)
Saline	<0.0001	1	0.132*	(0.046, 0.218)
		2	0.210*	(0.124, 0.296)
		5	0.275*	(0.189, 0.361)
		10	0.374*	(0.288, 0.460)
		20	0.492*	(0.406, 0.578)

* denotes significance

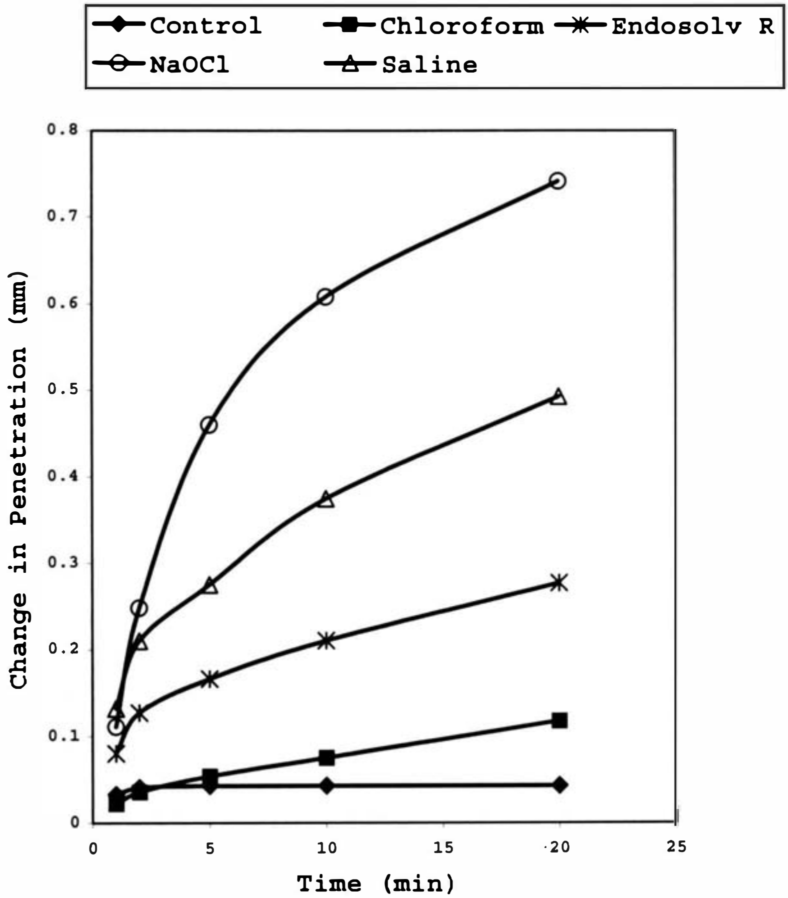

Figure 1 Penetration Across Time

Discussion

Resorcinol (also known as 1,3-dihydroxybenzene) is a white or off-white crystalline aromatic chemical that is commonly used in the manufacture of tires and rubber products, high performance wood adhesives, fire retardant plastic additives, and UV light stabilizers. Resorcinol is also used as a chemical intermediate in the manufacture of dyes and dyestuffs, pharmaceuticals, agricultural chemicals, plasticizers, explosive primers and polyurethane chain extenders (7). The chemical structure is that of a benzene ring with two hydroxyl groups attached (Figure 2). Although it has been used industrially for many years, it has just recently found its way into dentistry. Teeth treated with the resorcinol-formaldehyde resin pastes have been labeled as "red teeth" due to the ability of resorcinol to stain teeth a reddish hue. It is theorized that resorcinol injected or packed into root canals infiltrates the dentinal tubules, causing the dentin and cementum to turn red in color. This is clinically discernible on the teeth treated with this material (8).

One of the difficulties in removing resin pastes from the root canal system stems from the ability of the paste material to infiltrate the dentinal tubules and, upon setting, utilize the tubules as a locking mechanism. With resorcinol, Min-Kai and Man-en (9) found that resorcinol was able to infiltrate the dentinal tubules up to a depth of one-fourth to one-third the total length of the tubules. In the present study, dappen dishes rather than extracted teeth were used in an effort to ascertain if there was any softening effect of the various solvents without introducing the dentinal tubules as a variable.

In a humidor at a temperature of 98.6°F, the resorcinol did not set even after a one-month time period. Typically, the resin paste will remain in the root canals longer than one month and as such will achieve a hard set after a longer period of time. As a result of the pilot studies it was found that the resin paste would achieve a hard set in air at room temperature.

Upon reviewing the literature, only one study was found that dealt with the resin formaldehyde pastes and the ability of solvents to soften the set material. Cohen (5) examined the efficiency of several solvents on ten different pastes, two of which contained resorcinol, Forfenan (Spad, France) and Resoplast (Pierre Roland, France). The results showed that the solvent, dimethyl sulfoxide (Aldrich Chemical Company, Inc., U.S.A.) and Resosolv (Pierre Roland, France) showed a softening effect on the resin pastes after immersion for up to one month. Due to potential harmful effects of the solvents on the human tissues and the environmental effects due to inhalation of the vapors, these solvents are not suggested for use in a clinical environment. Additionally, these materials are not commonly a part of the endodontic inventory. The present study is the first to examine the softening effect of some commonly used endodontic solutions on a formulation of the resorcinol-resin paste.

Chloroform, also known as trichloromethane or methyltrichloride, is a colorless liquid that is used as a retreatment solvent for root canals obturated with gutta-percha. In this study, chloroform did not have any softening effect on the resorcinol resin. This is in agreement with Cohen (5), who found no significant effect of chloroform on resin-based pastes.

Endosolv R is a solvent which is recommended for use in softening phenolic-type resin fillings. Since resorcinol in its basic structure exhibits a cross-linked phenolic ring, it was reasoned that this solvent might have a softening effect on the resorcinol-formalin paste. The results showed that Endosolv R began to soften the resin after two minutes and continued to show a softening effect until the end of the experiment period. Cohen (5) also showed that Endosolv R had an effect on the resorcinol-formalin resins. In the present study, Endosolv R appeared to become incorporated into the paste, softening it without actually dissolving it.

Surprisingly, the results in the present study showed that both saline and sodium hypochlorite exhibited a significant softening effect within two minutes when placed in contact with this particular resorcinol-formalin resin paste. Sodium chloride and sodium hypochlorite are both water solutions that contain sodium ions. This fact may have contributed to the softening effect of the resorcinol-formalin resin.

This was a bench-top pilot study whose results might not be indicative of the results that would be obtained in a clinical environment. Further studies are needed to determine if the results of this study can be duplicated in a tooth model environment. If the results of the next phase of in-vitro studies prove to be successful then the final and ultimate goal would be to try these materials in a clinical setting. Until such time in-vitro studies can be completed, it is suggested that a clinician who is faced with retreating a root canal system obturated with a hard resin paste might first attempt to soften the material by using sodium hypochlorite or saline as solvents in conjunction with hand filing. This could be attempted before condemning the tooth to extraction or to using rotary burs or ultrasonics and increasing the chances of perforation.

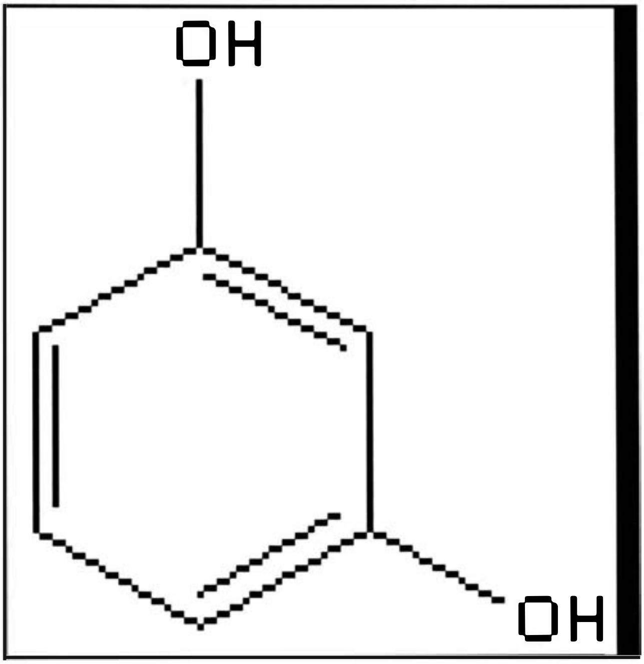

Figure 2 Resorcinol Structure

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Vita

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